THE LATERAL LINE OF POLYODON SPATHULA*

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CONTENTS

I. Historical

The lateral line system of fishes has long been known as a system of dermal canals lying upon the head and along the sides of the body. It was described in 1664 by N. Stenois and until 1850 it was regarded as an organ for the secretion of mucus.

Leydig ('50) describes the general appearance and location of the canals, the nerve supply and histology and concludes that it is sensory in function. Vogt ('56) advanced the theory that it was connected with the lymph system, altho he agrees with Leydig that it is not a mucus producing organ. Franz Schulze ('61) in working on the lateral line organs of Perca fluviatilis agrees with Leydig and Vogt in calling it a sensory structure, but the following year M'Donnell ('62) states that it "secretes some fluid which is poured forth from the skin as an excretion." Following these earlier workers we have the papers of R. R. Wright, Allis, Collinge, and Cole. R. R. Wright ('84) in describing the lateral canal of Amiurus, gives the number of pores and nerve hillocks (sensory ridges) as equal in number and forty on each side of the fish. In the specimens of Polyodon examined I find that the number of sensory ridges is much greater than the number of the branchlets and not equal as he found them in Amiurus.

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The condition of the canal as found in Amia calva by Allis ('89) resembles in many ways that of Polyodon. He describes the canal as turning downward at the caudal end and passing between two tail fin rays and not in a ray as in Polyodon. In fig. 49, Plate XLII he shows the ridges as intermediate between the branchlets, not at the bases of the branchlets as was found in Polyodon.

In the description of the lateral line of Polyodon folium by Collinge ('94) he states that "during its course from the caudal to the cranial region there is a gradual but distinctly appreciable enlargement in its diameter." He gives the number of branchlets as varying from 32–35, part on the ventral side and part on the dorsal side. The smallest number found in Polyodon spathula was 41. He found the branchlets from 12–17 mm. in length, while in the specimens of Polyodon spathula which I have examined none of the branchlets exceeded 9 mm. in length, but this may be due to the comparatively small size of the specimens examined.

Mention should be made of the work of G. H. Parker ('02 and '04) upon the function of the lateral line organs. In the summary of his paper he says, "The lateral line organs are stimulated by water vibrations of low frequency—6 per second." Some other work has been done on the physiology of these organs and a good deal in attempting to determine the embryology.

Brohmer ('08) in working with embryos of Spinax niger found that in 36 mm. embryos the lateral line, seen in toto, appeared as a white line. In the 45 mm. stage he found that the white dots along the sides of the lateral line which he had supposed, in the general examination to be Lorenzian ampullae, were in reality the openings of the branchlets. He says (free translation) "On either side of the lateral line, were noticed rows of white spots, the openings of the sense bodies. The openings arranged themselves with somewhat of regularity on the right and left sides. The adjoining bodies united to form the lateral line, and the communicating cavities formed the lateral canal." If this represents the embryonic condition of the canal of Polyodon as well as that of Spinax, it would account for the position of the branchlets always on the dorsal or ventral sides of the canal, never on the lateral side, which would naturally be expected if the branchlets were simple evaginations from the canal, or if they were the tubes connecting the depressed organs with the surface.

This would also explain the enlargement of the canal at each sensory ridge, as well as the tendency of the sensory ridge to pass up onto the opposite side of the canal to that from which the branchlet is given off. The closing of the openings of some of the bodies would account for the fact that some of the ridges are without a branchlet. In speaking of this alternating opening of the bodies upon the right and the left sides he says that the two sided opening of the canal perhaps aids in the determination of the direction of the sensation, since the stimulus will have a different effect upon some of the bodies or nerve ridges than upon others whose branchlets are turned away from the source of the stimulus. In this way the fish is enabled to orient itself with respect to the stimulus. An interesting fact in connection with this theory is that in the Polyodon, a bottom swimmer, the majority of the branchlets come from the ventral side of the canal, which is not what would be expected if this suggestion is correct.

Johnson (1917) in his description of the lateral line system of Selachians finds that the sensory epithelium is practically uniformly distributed along the canal except for the decrease in size toward the caudal end, and that it is located on the superior medial part of the canal. He finds the branchlets (tubules he calls them) all opening from the ventral side of the canal.

II. Material and Methods

The material used in this investigation consisted of the right lateral lines of two Polyodon spathula. Both lateral lines had been removed from the fishes, so there was no way of knowing definitely the total lengths of the specimens. In order to gain some idea of the size of the fish from which the lateral lines had been taken thirteen Polyodon of various sizes were examined. The total length of the fish from the tip of the "bill" to the tip of the caudal fin, as well as the length of the lateral line measured from the first branchlet posterior to the gills to the termination of the canal upon the dorsal part of the caudal fin, was carefully determined for each specimen. The length of the lateral line expressed as a percentage of the total length of the fish was found to be approximately 47%, the average for the thirteen specimens examined. Thus the length of the larger fish whose lateral line was 17 inches long must have been about 36 inches in length, and the smaller fish with a 7 inch lateral line must have been about

14.5 inches long. Of course, this gives only an estimate of the lengths of the fish. All the measurements were made from preserved material.

The two lateral lines had been removed by cutting a strip about three quarters of an inch wide, in the case of the larger fish, and one half inch wide from the smaller fish, and deep enough in both cases to ensure getting all of the dermis. The lateral line from the larger fish had been fixed in Formol-Corrosive-Acetic and had been kept in 80% alcohol for about a year. The shorter lateral line had been preserved but a short time in alcohol, after fixation in Trichlor-Acetic.

Charts showing the number of the branchlets and tube pores as well as the lengths of these branchlets and the intervening lengths of the canal were drawn to scale before the strips were cut (Figs. 1 and 2). Both strips were placed in acid alcohol (.5% HCl. in 70% Alcohol) for from two to four hours and then stained in toto in Haemacalcium for from 24 to 36 hours. The canal from the larger fish was then cut into convenient lengths run thru the alcohols and xylol, imbedded in paraffin and cut longitudinally. The other canal, stained and imbedded in the same way, was cut transversely. The longitudinal series was cut ten microns in thickness while the transverse series was cut twenty microns. The larger canal was the better preserved altho neither was in first class histological condition. The epidermis of the strip containing the shorter canal was nearly all destroyed in attempting to remove the hardened opaque mass of mucus so that the branchlets could be distinguished, with the aid of a dissecting lens, in making the surface drawing. The epidermis of the other strip was in a little better condition. The lengths of the sensory ridges in the lateral canal, which was cut longitudinally, were determined by means of an ocular micrometer; the lengths of the ridges in the transverse series were determined by counting the number of sections containing each ridge.[1]

[1] This work was done some time ago in the Animal Biology Laboratory of the University of Minnesota, at the suggestion of Professor Henry F. Nachtrieb, to whom I wish to express my most hearty thanks for his stimulating and very helpful advice. I had hoped to get more material and then make a more complete histological study but there seems to be no immediate prospect of doing this.

III. General Structure of the Lateral Line

The lateral line system as described by various investigators consists of several cranial branches, a main branch, and the lateral branch, or lateral line. The lateral line was the only part of the lateral line system studied. In Polyodon spathula the lateral line unites with the main canal by passing dorsad to the gills, and extends caudad from the gills along the sides of the fish. In the anterior portion of the body it is situated upon the dorsal half of the fish, but as it approaches the tail it comes to lie about half way between the dorsal and ventral portions. It is deflected downwards slightly as it reaches the tail, but upon entering the dorsal part of the caudal fin it runs upward, parallel to the fin rays and terminates a short distance from the tip of the tail. The lateral line, in preserved specimens, when viewed from the surface, appears as a whitish line extending along the sides of the fish, and the branchlets appear as shorter white lines extending dorsad and ventrad from this. These branchlets divide, as a rule terminating in the tube pores. (Figs. 1 and 2).

The number of branchlets varies in different specimens and even on the two sides of the same specimen. The number of branchlets found on four specimens of Polyodon is given below:

Right side.	Left side.
41	41
56	50
64	61
52	46

For convenience the lateral line from the larger fish, which was cut longitudinally, will be spoken of as the "Longitudinal series," and the lateral line from the smaller fish which was cut transversely will be spoken of as the "Transverse series."

a. The Longitudinal Series

The lateral line from the first branchlet posterior to the gills to the last branchlet on the caudal fin was 42.85 cm. in length. Thruout this entire length there were in all, 54 branchlets, ten of these were given off from the dorsal side of the canal, and 44, from the ventral side of the canal. In no instance did a branchlet start from the lateral or medial sides of the canal. Four of the ventral branchlets passed between the canal and the epithelium and terminated in the

epithelium, either entirely, or partly on the opposite side of the canal. All four of these branchlets were in the anterior region. On account of the amount of cartilage in the tail it was impossible to obtain a series of the posterior part of the canal; so the length of the canal which was sectioned, was 37.9 cm. in length and contained 44 branchlets. These branchlets terminated in from two to seven tube-pores. The more anterior branchlets, as a rule, had the larger number of pores, and hence were more branched. No opening of these branchlets was more than 9 mm. distant from the canal. Thus but a relatively narrow band, not over 18 mm. wide, contained the entire lateral canal and its branchlets. The cartilaginous nodules and "pit organs" could also be seen in the surface view, situated either over or near the canal. The nodules seemed more numerous in the posterior part, where they were scattered irregularly, while in the anterior part, they were nearly always found lying over the lateral canal. These nodules and "pit organs" will be described a little more in detail later on.

The features most clearly shown in the longitudinal sections were, the relation of the cartilaginous rings surrounding the canal and the unevenness of the sensory ridges, (fig. 4). The determination of the lengths of the ridges was a little more difficult than in the transverse series, due to the fact that it was hard to get the sections perfectly parallel to the canal. The lateral canal itself was not perfectly straight. Where a branchlet was given off there was often a slight divergence toward the side from which the branchlet originated. These irregularities in the plane parallel to the surface were, however far less pronounced than the wave like course in the plane perpendicular to the surface.

The cartilaginous rings surrounding the lateral canal thruout its entire length were of two kinds, (a) ring-like cartilages which enclose the canal in the troughs, or parts of the canal most distant from the surface, and (b) cylindrical or "drainpipe-like" cartilages, found always at the crests or parts of the canal nearest the surface. The ring-shaped cartilages enclosed those portions of the canal between the ridges, while the sensory ridges were always enclosed in the cylindrical cartilages, (fig. 4). The distance from one crest to another in the anterior part of the canal varied from 3.2 mm. to 4.5 mm. The crests of the canal very often came up to the base of the epithelium while the troughs were from .24 mm. to .48 mm. distant from the

base of the epithelium. Between the cylindrical cartilages, or "drainpipe-like bones," as they were called by Collinge ('96), there were from 12 to 14 of the ring-shaped cartilages in the anterior part of the canal. In the body region, at the base of the caudal fin, there were but one or two and sometimes none of the ring-shaped cartilages between the long cartilages. This change in the number of the ring cartilages was not abrupt, for from the middle of the body region there was a gradual diminution till the extreme condition, the absence of the ring cartilages was found at the base of the tail.

The cylindrical cartilages terminated either at the crest or a little caudad to it at the place where the canal began to descend. From this point they extended cephalad and mediad often reaching to nearly the lowest part of the curve. Thus the sensory ridges which lay primarily within these cartilages were situated in that part of the canal facing the anterior. The sensory ridges as well as the cylindrical cartilages in some instances extended a short distance caudad to the crest.

The branchlets were always given off from either the dorsal or the ventral side of the cylindrical cartilages at a point near the surface. A continuation of the connective tissue extended out surrounding the branchlet for some distance. The sensory ridge extended but a short distance caudad to the origin of the branchlet. Neither the sensory ridge nor any part of it extended out into the branchlet. This relation of the sensory ridge to the branchlet was followed out more carefully in the transverse series and will be discussed later. The sensory ridges which were situated in the cylindrical cartilages from which branchlets were given off showed apparently no difference in structure from those ridges which were not near a branchlet. Every branchlet, however, originated from one of the cylindrical cartilages containing a sensory ridge. In some instances branchlets arose from adjoining crests, while as many as five, in one instance, and often two, three and four ridges intervened between two ridges which were located at the base of a branchlet.

From one crest in the anterior part of the canal a small tube was given off from the lateral side of the canal. This was much smaller than the branchlets, both in length and in diameter. The sensory ridge and canal showed no special modifications at this point. It resembled a similar structure found in the transverse series, which

will be described more fully in that part of the paper. This opening was not counted as a branchlet.

That part of the canal which was cut was 37.9 cm. in length, and contained 126 sensory ridges and 44 branchlets, or an average of 2.86 ridges for every branchlet. The branchlets were not distributed uniformly, for there was a tendency for the branchlets to group themselves.

The measurements of the sensory ridges will be given more concisely and perhaps just as clearly in the following table. The eleven groups are the eleven pieces into which the lateral canal was cut for convenience in sectioning. The first column shows the number of branchlets in that section, the second column gives the number of sensory ridges, the third, the average length of the sensory ridges found in that division, and the fourth and fifth columns give, respectively, the longest and shortest ridges found in each division.

Branchlets	Ridges	Av. Length	Longest	Shortest
5	15	1.194 mm.	1.666 mm.	.830 mm.
6	9	1.473 mm.	2.075 mm.	.797 mm.
3	11	1.045 mm.	1.328 mm.	.581 mm.
4	11	1.004 mm.	1.411 mm.	.498 mm.
4	12	.837 mm.	1.666 mm.	.415 mm.
4	14	.652 mm.	1.328 mm.	.249 mm.
4	15	.655 mm.	.896 mm.	.332 mm.
4	14	.792 mm.	1.411 mm.	.581 mm.
5	13	.745 mm.	1.162 mm.	.249 mm.
2	6	.766 mm.	1.162 mm.	.581 mm.
3	6	.830 mm.	1.079 mm.	.415 mm.
44	126	.908 mm.		

This table and the chart of the lateral line (fig. 2) do not show the same number of branchlets but it must be remembered that only a part of the lateral canal was sectioned, or that part between the second branchlet from the anterior end and the eighth from the caudal end. There were 54 branchlets in the entire canal which measured 42.85 cm., and but 44 branchlets in the part sectioned which measured 37.9 cm.

b. The Transverse Series

The material used for this series was the right lateral line canal of the smaller fish, as stated above, and on account of the smaller size of the fish as well as the hardened opaque mucus covering the skin, it was much more difficult to chart the line and branches. It was possible, however, to make a series thru the entire lateral canal, from the gills to its termination upon the caudal fin.

The canal measured 18.1 cm. from the first branchlet posterior to the gills to the last branchlet on the dorsal part of the caudal fin. Thruout its entire length there were 61 branchlets, 53 of which were given off from the ventral side, and 8 from the dorsal side, (fig. 1). There were thirteen branchlets in the tail, all of which were on the ventral side of the canal. In studying the sections an additional branchlet was discovered originating from the lateral side of the canal. This branchlet resembled the others in everything but its position, which was between the canal and the epidermis, and parallel to the canal, so that it was not seen while making the surface drawing. This would raise the total to 62 branchlets. All of the branchlets were less branched than in the larger specimen, terminating in but from one to three tube pores. The majority of the branchlets did not branch at all, or else had a short dichotomous branching. Many of the branchlets would remain unbranched thruout nearly their entire course, then very near the end they would divide terminating in from one to three tube pores. The two charts show a marked difference in the branching of the branchlets and the number of tube pores, tho the branchlets are distributed along the canal in much the same way. Immediately posterior to the gills, the first two or three branchlets were not so close together as the next ten or twelve. Then followed a longer region extending nearly to the base of the caudal fin, with the branchlets more scattered. On the body, at the base of the caudal fin and on the fin itself, the branchlets tho shorter and less branched, were closer together. No branchlet terminated more than two and one-half or three millimeters from the canal: in other words, the entire canal and its branches were contained in a strip six millimeters wide on the body, and gradually diminishing posteriorly, till not over three millimeters wide on the caudal fin. As was found in the other series, the more anterior branchlets had a tendency to turn caudad after leaving the canal. Only one of the branchlets in this series

passed laterad to the canal in reaching the surface on the opposite side of the canal. In one case two branchlets were given off from the same ridge, one from the dorsal side, and the other from the ventral side of the canal.

The number and arrangement of the canal cartilages was not so carefully noted in this series. As in the longitudinal series, the sensory ridges were always found in the cylindrical cartilages, which were separated from each other by a greater number of ring-shaped cartilages in the anterior part of the canal than in the posterior part. The canal had the same wavy course tho perhaps not quite so marked as in the longitudinal series. In this series the crests scarcely ever came in contact with the dermal epithelium. The few exceptional cases where the cartilages of the canal came up to the epithelium were just about as numerous in this series as were the exceptions in the longitudinal series, or those cases where the cartilages did not come to the surface. In a short portion of the canal about one-third of the distance caudad, the top of the canal varied from .08 mm. to .22 mm. distant from the base of the epithelium. These figures do not mean that the above is the variation in one curve, but the longest and the shortest distances from the base of the dermal epithelium in the two slides in which the distances were measured. The difference between a crest and an adjoining trough would probably be quite a little less.

In this series as in the other, the sensory ridges were found in the anterior slope of the crest, terminating at, or just posterior to, the base of the branchlet, or at the crest if no branchlet is given off, and enclosed in the cylindrical cartilages. As before, there was no apparent difference in the structure of the sensory ridge whether a branchlet was given off or not. In the case of the double branchlet, or the one where a branchlet was given off from each side of the canal, the sensory ridge was a normal one, being .380 mm. in length. The average for this region was .336 mm. and the longest ridge was .600 mm. in length and had no branchlet. The number of sensory ridges intervening, between ridges in the cartilages from which branchlets were given off, varied from none to as many as six in one case (two-thirds of the distance back on the body). In seventeen instances there was no intervening ridge; in fourteen instances there was one ridge; in eleven instances there were two ridges; nine instances,

three ridges; five instances, four ridges; two instances, five ridges, and in one instance there were six intervening sensory ridges. As many as three consecutive ridges were found with branchlets, again showing the grouping of the branchlets.

The method of arrangement found in the body region seemed to be very much altered in the tail region. There were nine branchlets on the caudal fin with no sensory ridge at their bases. In two places two adjoining branchlets were found with no ridge at their bases nor an intervening ridge. The arrangement of the cartilages seemed less typical in the caudal fin. The canal toward the later part of its course in the caudal fin seemed to enter what might be called a jointed cartilaginous, fin ray. The differences in the epithelial lining of the canal will be described later.

The location of the sensory ridge in the canal was shown very well in this series (figs. 6 and 7). A narrow circular space filled with an indifferent mesenchymatous tissue, separated the cartilaginous canal from the inner or epithelial canal, which consisted of a single layer of flat epithelial cells thruout about one-half to three-fourths of the circumference of the canal, the remaining portion being occupied by the columnar epithelium or sensory ridge. The sensory ridge was uniformly found on the medial side of the canal, tho in some places there was a slight tendency toward the movement of the ridge up onto the side of the canal opposite to that from which the branchlet was given off. In one case, the anterior end of the ridge started a little way up on one side of the canal and in going caudad it passed to the normal position on the medial side of the canal and then passed up onto the opposite side from that on which it started. The longitundinal band of columnar epithelium, or sensory ridge, was always raised up upon a thicker mass of mesenchymatous tissue, which was well supplied with blood vessels and nerves, both of which entered thru openings in the cylindrical canal cartilages. The blood vessels often entered on the dorsal or ventral side, while the nerves entered thru an opening in the medial side. The central position of the sensory ridge, the top of the sensory epithelium reaching often to the center of the canal, was due, not only to the higher cells composing it, but also to the infolding of the ridge. This infolding was supported upon the mass of tissue underneath. The ridges terminated quite abruptly at both ends.

Just caudad to each ridge the canal lost its circular outline and assumed an oval shape, with the long axis perpendicular to the surface. There was in addition a rapid decrease in the size of the lumen, with a more gradual increase toward the cephalic end of the following ridge. This was especially noticeable in the tail region, where the size of the lumen diminished appreciably caudad to each ridge; in some places the lumen was almost entirely closed. The cylindrical portion containing the ridge was quite uniform in diameter in the transverse series but in the longitudinal series it was of considerably larger diameter in the median portion than at either end. In some cases the lumen of the "drainpipe-cartilages" assumed an elongated ellipsoidal form. This may have been due to a distortion during the preparation of the material.

In addition to the differences in the arrangement of the canal cartilages in the tail region, which has been described above, there was also a change in the epithelium of the canal itself. In general the epithelium of the body canal was of the flat pavement type, but in this region it was cuboidal. The entire lateral canal as well as the lumen became much smaller and the ridges were not so prominently elevated into the lumen of the canal. As nearly as could be determined with the available material there was a difference in the character of the ridges. In the caudal fin the sensory ridges were composed of deeply staining, long, narrow cylindrical cells, while in the body region, in addition to these cells, there was a type of cell less intensely staining and which often seemed to have its upper end dilated. A group of these cells would apparently make a little elevation above the rest of the ridge. The upper end of these cells was often much clearer and with proper stains it might have been shown to have contained mucus. These may be the surface mucus cells carried down with the nervous elements in the formation of the canals as suggested by Cole (98). Better material and a more careful study of these conditions would be necessary before a positive statement could be made.

The height of the epithelium in the various ridges, and the average height for the three regions of the canal was quite different. The average height of the sensory epithelium of the ridges of the first region, or the first thirteen ridges posterior to the gills was .032 mm.; that of the second region, or from a region about two-thirds of the way

back on the side of the body, was .027 mm. and the average height of several ridges on the dorsal caudal fin was .025 mm. The highest epithelium, .048 mm. in height, was found in the anterior region, while the lowest, .020 mm. in height, was found in the posterior region.

A short distance caudad to the branchlet which originated from the lateral side of the canal one of the sensory ridges was observed to commence upon the lateral side of the epithelial canal. Passing caudad in the series of sections the ridge was observed to pass onto the dorsal side of the epithelial canal and then almost over to the medial side. At the point where the ridge left the lateral side and came to lie more upon the dorsal side of the canal, an exceedingly fine tube was cut off from the lateral side of the canal, and passing thru a longitudinal distance of seven sections, or .14 mm., it opened to the surface. The average diameter of the tube was .02 mm. It broadened out at its termination on the surface to about .06 mm. in diameter, and posteriorly it was followed by a slight groove which gradually became shallower and finally disappeared. In many respects this tube resembled a branchlet, and very likely may have been either a developing branchlet or one that was closing, but I am unable to explain its position. Anterior to this opening the lumen of the canal was unusually large for the region, being .244 mm. in diameter. The lumen narrowed down to .112 mm. in diameter in the cylindrical cartilage immediately following which enclosed the posterior part of the ridge. The later part of the ridge was normal both in structure and position. At the caudal end of the cylindrical cartilage the lumen narrowed as usual, but to a much greater extent, being only .064 mm. in diameter.

The lateral canal used in this series was divided into seven pieces for convenience in handling and cutting. The following table will give the data grouped into seven divisions corresponding to the seven pieces into which the canal was divided for sectioning. There were 62 branchlets and 151 sensory ridges, or an average of 2.45 ridges for every branchlet. The first column shows the number of branchlets in each of the seven divisions, the second, the number of sensory ridges, the third column, the average length of the ridges in each division, the fourth and fifth columns show respectively, the longest and the shortest ridge in each division.

Branchlets	Ridges	Av. Length	Longest	Shortest
7	14	.536 mm.	.92 mm.	.14 mm.
8	16	.470 mm.	.62 mm.	.34 mm.
7	20	.336 mm.	.60 mm.	.14 mm.
12	35	.293 mm.	.78 mm.	.12 mm.
13	35	.250 mm.	.46 mm.	.10 mm.
3	7	.211 mm.	.34 mm.	.12 mm.
12	24	.290 mm.	.52 mm.	.08 mm.
62	151	.3408 mm.		

One of the most striking things shown in the table is the decrease in the average length of the ridges toward the caudal end of the canal. The table giving the averages for the longitudinal series shows the same decrease in length. It must be remembered, that the eleven divisions of the longitudinal series correspond to the first six divisions of this series, the seventh being the part on the caudal fin which it was impossible to cut in the longitudinal series. In the above table there is a gradual decrease in the length of the ridges in the first six divisions, or that part of the canal lying on the body of the fish, as the canal approaches the tail, and then a marked increase in the seventh section or that part of the canal lying on the caudal fin. In the smaller fish the ridges do not begin to increase in length until the canal reaches the tail, while in the larger specimen the increase begins on the posterior part of the body.

The fact that in nearly every instance the ridges terminated so near the base of the branchlet and extended some distance cephalad suggested that the sensory ridge or some portion of it might be continued out into the branchlet. Nothing of the kind had been observed in either series, but over one-half of the branchlets in the transverse series were carefully reexamined for the presence of sensory epithelium in the branchlets. As has been stated before, the ridge occupied the medial part of the canal extending up slightly, at times, upon the side of the canal opposite to that from which the branchlet was given off. The branchlet emerged from the canal from the lateral part of either the dorsal or ventral sides of the canal and ran nearly parallel to the surface for some distance. Thus the sensory ridges occupied the medial half of the canal and the branchlets opened into the lateral

half of the canal. The sensory ridge was never seen to divide or branch. A careful examination of the epithelial lining of the branchlets failed to reveal any sensory epithelium. The flat pavement epithelium of the canal, very soon after entering the branchlet became more cuboidal, resembling that found in the caudal portion of the canal. Toward the peripherial ends of the branchlets the simple cuboidal epithelium gradually became stratified, and passed over at the tube-pore without any abrupt change into the general epithelium of the body surface. Only the proximal parts of the branchlets were enclosed in the cartilaginous rings.

No careful investigation into the nature of the pit organs was attempted, on account of the conditions of the material and the thickness of the sections. All of these organs observed in the neighborhood of the canal were encased in a cup-shaped cartilage with a layer of columnar epithelium across the top of the "beaker" or cup-shaped cavity. Eleven of these pits were observed in the transverse series.

A rather unusual structure was observed in both series, namely, the apparent combination of one of the pit organs and a crest of the lateral canal (fig. 6). Three of these were found in the longitudinal series and one in the transverse series. The caudal end of the drain-pipe cartilage where it approached the surface was elongated laterally forming a cup or "beaker-shaped" cavity. The rim of this cavity was on a level with the lower columnar layer of the epidermis and the bottom was open into the lumen of the cylindrical cartilage. There was apparently no open communication between the pit organ and the sensory canal for the opening was covered by quite a thick membrane. As far as was observed there was no difference in the structure of these organs and the pit organs which were in no way connected with the canal. This relation may have no special significance but be due to the accidental fusion of the cartilage forming the cup-shaped cavity with the canal cartilage. The investigation has not been extensive enough to warrant any conclusions with regard to these structures.

The location of the nodules, or placoid scale-like structures, pits and these openings will be shown in the following table as they were found in the longitudinal series. The grouping into eleven divisions corresponds to the eleven pieces into which the lateral canal was cut

for convenience. The first column gives the number of pit organs found in the immediate vicinity of the canal, the second column, the number of "openings" or combination of pit organ and canal cartilage, while the third column gives the number of nodules in each division. Where two or more scales had a common base they were counted as one. The last column gives the number of crests in each division which had no surface marking; neither pits, "openings," nor nodules. The table shows very clearly the anterior position of the pits and the "free crests," and the posterior location of the nodules.

Pits	Openings	Nodules	"Free crests"
2	2	2	10
1	0	6	3
2	0	6	4
1	0	5	4
2	0	8	3
1	0	11	4
1	1	13	1
0	0	12	1
0	0	11	2
0	0	7	0
0	0	7	0
—	—	—	—
10	3	88	32

IV. Summary

1. As the lateral canal passes caudad from the gill region its diameter gradually becomes smaller.

2. The sensory ridges are located upon crests or parts of the canal approaching the surface. The lumen of the canal here is always larger than just anterior or posterior to the ridge.

3. The longest ridges are in the anterior region. There is a gradual diminution in length going caudad upon the body until just before the tail is reached, or upon the tail itself, where there is a slight increase in length.

4. No branchlet, except on the caudal fin where there seems to be a great irreguarity, is given off without a sensory ridge at its proximal end. Ridges may or may not occur between the branchlets.

5. The branchlets tho grouped to a slight extent are given off thruout the entire length of the lateral canal.

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